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Archaeometric characterization of pottery from the Iron Age hillfort of Pintia (Valladolid, Spain)

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ABSTRACT

This paper presents the results of an archaeometric analysis of pre-Roman and Roman ceramics from the Vaccean Iron Age hillfort of Pintia (Valladolid, Spain). The study assesses degrees of romanization and hybridization by investigating changes in local ceramic production and the dissemination of new technologies with the arrival of Roman rule. Thin-section petrography, XRD, and geochemical analyses (using XRF) have been utilised on a selection of pre- and post-conquest vessels from habitation contexts. This work goes beyond traditional typological analyses to shed light on the resilience of 'Second Iron Age' communities, who's ceramic traditions largely persist into Roman times, albeit with some changes, like shifts in the preferences and location of raw materials.

1. Introduction

The Iron Age of the Iberian Peninsula represents a socially dynamic period. A local group called the Vacceans are settled in the Middle Douro Valley from the end of the V century BC and are conquered by the Roman Empire in the I century BC. The Vacceans are a loose grouping of peoples that are defined through shared settlement layouts and patterns, material culture and funerary rituals.

One of the most important Vaccean complexes is called Pintia and is located in the municipalities of Padilla de Duero and Pesquera de Duero, in the Eastern part of the Valladolid province (Spain) (Fig. 1). The hillfort is situated next to the River Douro and uses part of the riverbank as a natural defence. The site is surrounded by a mud wall and ditches and has an area of 25 ha. Recent archaeological excavations have shed some light on the urbanism and romanization of the site (Sanz and Velasco, 2003; Coria, 2021). Several 'Second Iron Age' occupation levels with mudbrick houses were recorded dating from the IV century BC until the I century BC. Afterwards, a Roman level occurs which brings key socio-economic and infrastructural changes such as stone architecture and public buildings along with the introduction of coins and imported Roman pottery. Pintia, however, then loses its independence and is integrated into the imperial administration as a *mansio* registered in the Antonine Itinerary (Sanz, 1997: 21; Repiso, 2017: 70).

Apart from the urban area of the main settlement, Pintia yielded the remains of a cremation necropolis, called Las Ruedas (Sanz, 1997) and the Carralaceña pottery workshop, which was located on the riverbank opposite the main site, presumably to avoid fires and air pollution during production (Fig. 1). Carralaceña has the largest Iron Age pottery kilns ever recorded in the Iberian Peninsula (4.5 × 8 m), which was in use during the first half of the I century BC (Escudero and Sanz, 1993). Unfortunately, kiln samples were not available for study and could not be included in this work.

All of these features provide information about the Vaccean culture of the area and the process of romanization, as further evidenced by the adoption of certain material elements such as *terra sigillata* and coins, along with stylistic changes to some existing pottery types (Blanco, 2015). New public construction inside the *oppidum,* as documented through aerial photography, also evidences sweeping changes brought by Roman rule (Sanz et al., 2003). Scholars struggle, however, to answer key questions related to the process/timescale of romanization and to what degree it permeates society. We believe greater clarity can be achieved by examining shifts in quotidian classes of material culture, such as pottery, which is already deeply embedded within Vaccean society when the Romans arrive. The pottery assemblage, being widely circulated and the best-represented class of material culture recovered for all periods, can provide a robust and nuanced dataset with greater potential to inform on cultural transformation and hybridity. This paper applies an archaeometric approach to pre and post-conquest pottery,

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Fig. 1. Location of the archaeological site of Pintia, Las Ruedas necropolis, and the pottery workshop of Carralaceña (Valladolid, Spain).

providing an extensive dataset that can be applied to understanding changes to daily life in the area with the transition to Roman rule, through the lens of ceramic production, exchange, and consumption. Additionally, this study provides a much needed archaeometric dataset of Iron Age pottery from the Vaccean areas on the northern plateau of the Iberian Peninsula. Until now, archaeometric studies have largely been focused on regions occupied by the Celtiberians (García-Heras, 1994a, 1994b, 1997, 2005; González Rodríguez et al., 1999; Igea et al., 2008; Sánchez Climent, 2016; Sánchez-Climent et al., 2018) and Iberians (Tsantini, 2007; Cultrone et al., 2014; Dorado, 2019), whereas in the Vaccean areas only one study has so far been published (Escudero, 1999a).

2. Archaeological phases and ceramic assemblage

This study focuses on the three most recent occupation levels at Pintia which were documented during the latest archaeological excavations (1998–2006). Phase I (*ca.* 110 – *ca.*70 BC) and II (*ca.* 70 – *ca.* 15 BC) are Vaccean levels. Phase III represents the Roman occupation of the settlement and is dated from *ca.* 15 BC to *ca.* 400 CE. A large ceramic assemblage has been unearthed at the site for these periods, though Phase II, which was poorly preserved in general, produced comparatively less.

Throughout these archaeological phases a range of pottery types and wares have been recorded, which are comparable to assemblages from other sites in the northern plateau of the Iberian Peninsula (Sanz, 1997: 226, 282; Blanco, 2001, 2010, 2015, 2017, 2018a; Escudero, 1999b; Romero, 1984, 1991). A summary of wares and types will be provided below, but for a quantitative typological analysis of the ceramics from Pintia see Coria (2021). Some forms are associated with Vaccean levels only, whereas others carry on after the Roman conquest of the site (Fig. 2). The most common Vaccean category is Fine Orange Ware, which consists of ceramics fired in an oxidising atmosphere and usually painted in either red or brown, though sometimes multiple colours are used. This ware is used for serving types such as bowls, tumblers, drinking cups (Fig. 3, 1, 2 and 7), pitchers, goblets (Fig. 3, 4), platters, cups, and lids, together with mortars (Fig. 3, 15) and bottles for containing liquids and oils called *unguentarium* (Fig. 3, 8). Ceramics for mixing wine and alcoholic drinks like craters (Fig. 3, 5) and funnels are also made of this ware, along with large storage vessels called *pithos* (Fig. 3, 3 and 9). The use of Fine Orange Ware carries on during the Roman occupation (Phase III).

Vaccean Common Ware represents the second most common pre-Roman production. It consists of coarse wares fired in both oxidising and reducing atmospheres. The ware is mostly used for cooking pots (Fig. 3, 10) but platters, lids, casseroles, bottles, craters, and *pithoi* have also been found. Vaccean Common Ware, like Fine Orange Ware, is still used after the Roman conquest (Phase III). Grey Ware (Fig. 3, 11-12) consist of burnished vessels that are often seal impressed and intended to imitate silver vessels. Only bowls and goblets have been recorded in Grey Ware at Pintia, in contrast to a much wider range found at other Vaccean hillforts like Cauca (Blanco, 2001). Their chronology is well established, dating from 130/125 to 75/70 BC elsewhere. However, some individuals at Pintia were securely dated to Phases II and III, which suggests either their continued use or that they were reused or retained as heirlooms. Black Burnished Vessels (Fig. 3, 13) are a category of fine ware fired in a reducing atmosphere and decorated with knife incisions and grooves (Romero et al., 2012). These vessels are only found during Phase I and are unique to Vaccean area, perhaps reflecting a distinct form of local identity. Finally, one group, which we have termed Proto-arevaci Ware (Fig. 3, 14), is rare at Pintia but has parallels with the Celtiberian area of the Upper Douro Valley (Romero, 1984, 1991).

Along with these local wares, some Roman ceramic types were unearthed at Pintia that are common in this part of the Iberian Peninsula during the I century AD (Blanco, 2017). Roman Cooking Ware, used for cooking pots (Fig. 3, 17) and Roman dishes or *paterae* (Fig. 3, 16) were regularly uncovered. *Paterae* suggest the addition of ‘frying’ to the cooking repertoire, representing a significant culinary change. Roman Common Ware, used for cups, platters, pitchers, covers and mortars (Fig. 3, 15) was also regularly found.

3. Methodology

409 ceramic samples were selected from all phases for a macroscopic ware analysis using a stereomicroscope. The number of sherds analysed by ware and phase were selected in rough proportion to their relative abundance at Pintia (Coria, 2021). A full breakdown is provided in Supplementary Information, Appendix 1. The macroscopic analysis focused on the following parameters: ceramic form, matrix characteristics (including abundance (%) of inclusions and voids, distribution, compactness, firing atmosphere(s), surface treatment(s)), manufacturing technique, and post-depositional alterations (Cuomo di Caprio, 2007; Gámiz et al., 2013; Orton and Hughes, 2013; Druc and Chavez, 2014) (Supplementary Information, Appendix 2).

This initial work led to the selection of a representative number of sherds for further archaeometric characterization using thin-section petrography, XRD, and XRF. This programme of analysis was designed to generate complementary information about provenance and technology to the typology. Sample size was limited necessitating a minimally destructive approach, so a specialised protocol for elemental geochemistry using XRF analysis as described below was utilised.

38 samples were selected for thin-section analysis. The samples were studied in transmitted light using a Leitz 12 petrographic microscope. Light micrographs were taken with a Leica EC3 digital camera mounted

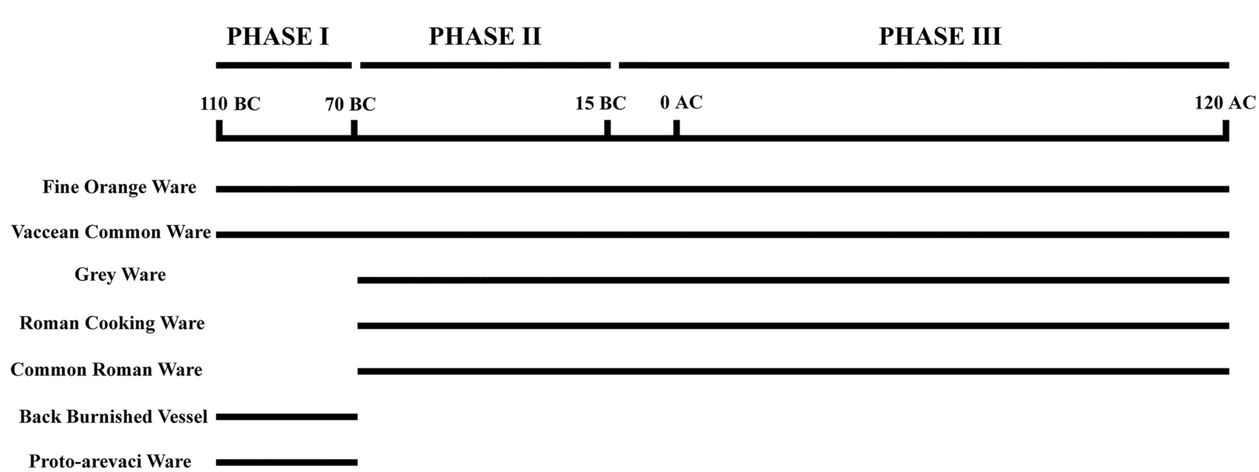

Fig. 2. Archaeological phases and chronology of ceramic repertoire.

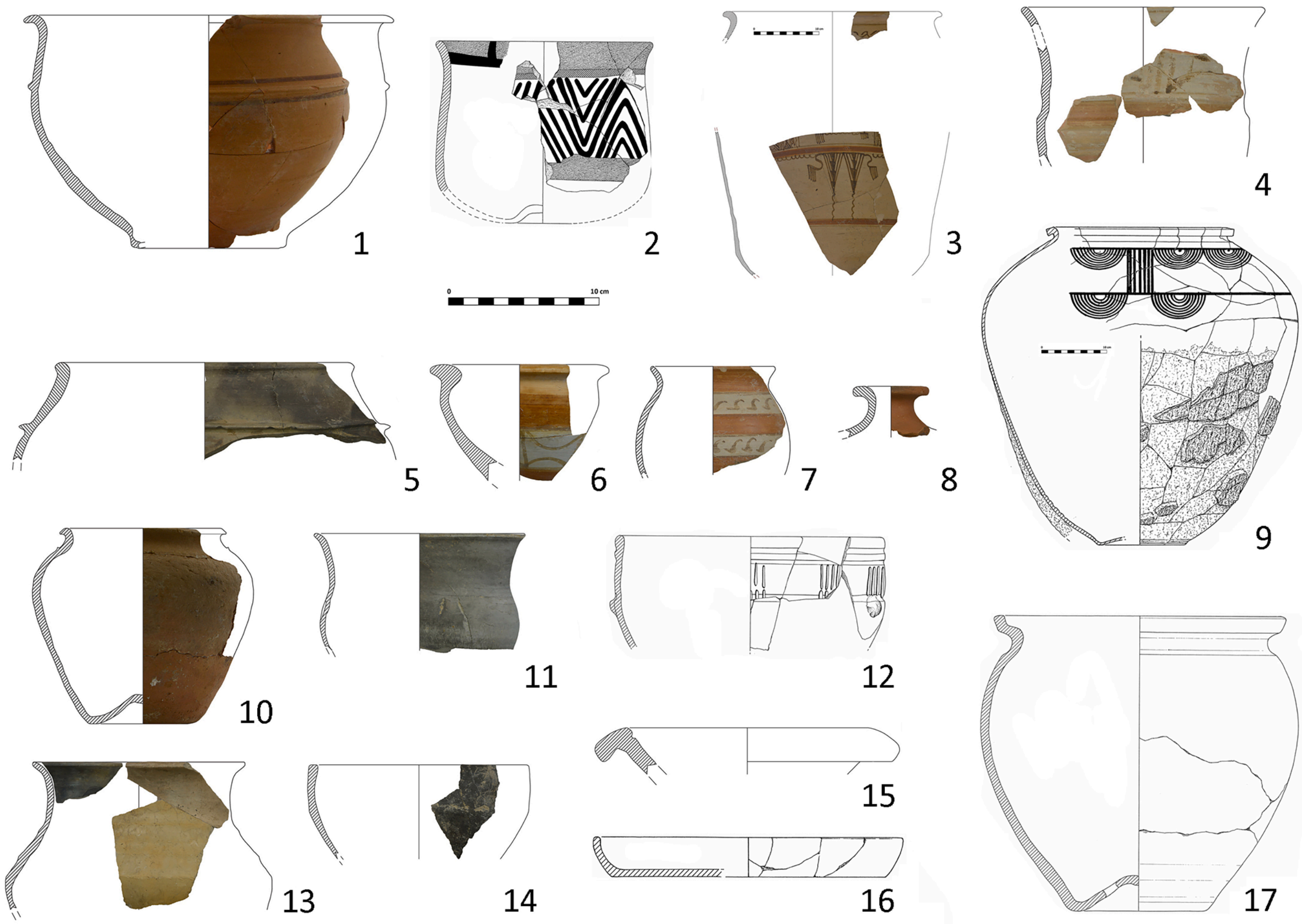

Fig. 3. Some analysed forms of Fine Orange Ware (1-9), Vaccean Common Ware (10), Grey Ware (11-12), Black Burnished Vessel (13), Proto-arevaci Ware (14), Roman Common Ware (15) and Roman Cooking Ware (16-17). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

on the microscope. To aid the identification and comparison of petrofabrics, tiled images of an area measuring 1 cm^2 on each thin–section were produced. Petrographic descriptions (Supplementary Information, Appendix 5) include rock and mineralogical identifications and descriptions of the clay matrix, and textures utilising systems described in Stoops (2003), Quinn (2013), and Whitbread (1989). The non-plastic fraction was quantified by using comparison charts for visual percentage estimation (Matthew et al., 1991).

109 sherds were selected from the different wares and aided by petrography for XRD analysis to reinforce the petrographic data, further characterise the mineralogy of the clay matrix, and gain an understanding of firing temperatures utilising established methodologies (Cultrone et al., 2001; Maggetti et al., 2011; Linares et al., 1983; Roberts, 1963; El Ouahabi et al., 2015; Grapes, 2006). XRD patterns and estimates of firing temperature of samples are provided in the Supplementary Information, (Appendix 3 and 4). 1.250 g of sample was powdered as described below in the XRF methods section. The samples were analysed via XRD before the addition of binder and pelletising for analysis via XRF. The analysis took place on a Panalytical Aeris XRD with a CuKα1 emitter. Measurements were taken from 5 to 70° 2Θ at a step size of approximately 0.0054° at 39.5 s per step. The powdered sample was placed in a circular sample holder with a diameter of 32 mm and a depth of 3 mm. A nickel-beta filter was used on the incident side, along with 0.04 rad soller-slits inserted on the both the incident and detector side of the beam. The analytical configuration also included a ¼° divergence slit, a 20 mm beam mask, a beam knife in the 'hi' position, and a 9 mm antiscatter slit. The total time for the analysis of each sample was 33 m and 32 s. The analysis of the results was completed using the 'high score' proprietary software package by Panalytical.

WD-XRF was selected to generate elemental geochemical data suitable for developing chemical fingerprints. WD-XRF was chosen over another viable alternative available to the authors, ICP analysis, due in part to budgetary constraints. The former allowed a larger sample-set to be analysed for geochemistry in this study, which is crucial as this dataset is the first of its kind for the period and region and as such represents an important foundation on which future work can be developed. The relatively low amount of available sample (10% of what is typically used for analysis on the instrument) meant that a fewer number of elements (14 total) could be reliably quantified utilising our protocol. These elements, however, all showed good agreement with certified reference materials (CRM) (Table 1). Two widely available CRMs, one rock and one soil, were chosen to best cover the expected range of elemental concentrations occurring in our samples. They are GBW07109 (rock) and NCSDC87103 (soil). The 14 elements utilised in our analysis fell within the uncertainty values reported for these CRM's or had varied from reported values by less than 5%. The authors believe an approach focusing on a fewer number of well quantified elements is more robust than one utilising a greater number of elements poorly correlated to CRMs. The latter is, unfortunately, increasingly common in archaeological work (see Killick, 2015; Speakman and Shackley, 2013 for particularly useful commentary on the misuse of XRF in archaeology). 36 samples were selected, again based on the macroscopic

Table 1
Geochemical composition of analysed samples.

SAMPLE	CHRONOLOGY	PETROFABRIC GROUP	GEOCHEMICAL GROUP	SiO2	Al2O3	Fe2O3	TiO2	CaO	K2O	MgO	Na2O	P2O5	Rb	Sr	Y	Zn	Zr	LOI
E1-1301-1	Phase I	3	B	57.12	16.28	4.53	0.40	2.59	2.33	1.34	0.23	0.12	133.20	143.60	35.40	51.90	304.70	15.057
B1-1230-25	Phase III	4	B	55.76	25.15	5.27	0.29	0.77	2.82	1.39	0.28	0.15	138.40	216.30	33.10	133.30	200.20	8.126
C1-1617-3	Phase II	4	B	54.23	22.71	5.60	0.35	1.31	2.68	1.34	0.21	0.38	116.70	297.30	34.00	111.80	227.40	11.194
E1-1318-9	Phase I	3	B	57.99	22.53	3.42	0.51	1.67	1.51	0.51	0.18	0.90	75.00	334.00	22.00	54.20	283.10	10.793
B1-1439-10	Phase I	5	C	35.84	14.81	5.38	0.32	19.67	2.90	1.12	0.26	0.20	208.30	354.10	19.30	132.10	166.90	19.503
SED-001	–	–	–	40.49	7.02	1.72	0.22	14.79	1.70	2.15	0.08	0.11	88.20	532.10	8.90	131.70	211.10	31.7299
SED-002	–	–	–	24.10	5.85	1.86	0.21	27.77	1.42	9.58	0.23	0.07	106.40	495.40	23.40	82.70	246.90	28.9035
SED-003	–	–	–	57.56	7.13	1.70	0.14	4.54	1.90	1.01	0.10	0.07	95.00	424.40	15.10	34.40	164.00	25.865
SED-004	–	–	–	65.32	6.68	1.25	0.23	0.29	1.63	1.16	0.09	0.03	85.90	46.20	18.60	42.00	218.30	23.3175
SED-005	–	–	–	37.64	9.75	3.75	0.28	14.22	1.95	6.37	0.12	0.06	138.80	644.60	35.60	74.30	200.60	25.8534
SED-006	–	–	–	45.03	19.17	6.48	0.47	4.92	4.17	3.26	0.19	0.15	270.10	187.10	15.60	98.80	198.60	16.151
SED-007	–	–	–	52.04	11.09	2.43	0.15	4.05	2.68	3.07	0.26	0.13	132.30	157.00	7.50	46.30	88.50	24.096
SED-008	–	–	–	57.15	5.90	1.02	0.14	8.13	1.99	0.97	0.22	0.13	96.30	116.20	10.10	62.00	180.50	24.344
SED-009	–	–	–	17.42	5.84	2.02	0.16	35.16	1.25	9.77	0.12	0.18	87.50	0.16	4.20	72.00	87.60	28.087
A1-13008-3	Phase III	1A	B	54.87	23.84	4.20	0.45	0.98	3.80	1.12	0.23	0.74	181.60	118.10	541.60	48.60	256.90	9.764
A1-13022-4	Phase III	1A	B	61.33	22.44	4.27	0.53	0.76	2.29	0.92	0.23	0.12	121.90	190.30	30.10	61.90	263.20	7.106
B1-1232-4	Phase III	1A	C	44.72	17.19	4.99	0.51	11.13	4.07	2.45	0.27	0.35	230.30	461.10	31.00	130.70	215.40	14.319
B1-1377-1	Phase II	1A	B	60.39	18.08	4.07	0.46	0.89	2.42	0.91	0.33	0.10	130.20	106.10	22.60	78.50	297.30	12.352
C1-1506-4	Phase III	1A	B	59.40	21.71	4.10	0.50	1.46	2.24	0.93	0.27	0.10	164.10	168.00	23.90	59.80	228.20	9.287
C1-1511-2	Phase II	1A	B	59.22	21.56	4.37	0.46	1.29	2.36	0.96	0.31	0.07	169.70	148.10	29.70	60.60	237.10	9.4061
C1-1634-4	Phase II	1A	A	47.29	20.45	6.43	0.47	5.94	4.97	1.81	0.27	0.30	218.20	473.50	55.10	99.70	189.10	12.073
D1-1127-9	Phase III	1A	B	58.61	22.36	4.77	0.48	0.67	2.16	0.61	0.19	0.07	146.50	175.20	27.20	59.40	242.00	10.0722
D1-1136-7	Phase III	1A	B	58.96	21.88	3.51	0.49	1.25	2.22	0.85	0.25	0.33	139.00	352.20	30.80	61.60	244.70	10.273
D1-1137-5	Phase III	1A	B	59.23	22.31	3.46	0.52	1.43	2.18	0.86	0.21	0.31	154.80	351.80	18.60	52.00	241.20	9.501
E1-1318-21	Phase I	1A	A	48.75	22.06	6.28	0.47	5.31	4.84	1.87	0.26	0.77	294.50	375.10	35.00	154.60	164.00	9.391
E1-1318-6	Phase I	1A	A	48.37	21.90	6.63	0.45	5.04	4.58	1.79	0.22	0.36	297.30	310.50	52.60	100.20	174.90	10.662
A1-13022-2	Phase III	1C	B	59.52	23.76	4.27	0.53	0.71	2.48	0.70	0.21	0.29	158.40	191.20	18.80	65.30	234.30	7.527
A1-13023-2.1	Phase III	1C	B	59.06	23.58	5.02	0.45	0.70	2.58	0.66	0.23	0.20	143.80	153.00	42.50	88.30	218.40	7.518
A1-13022-372	Phase III	1B	B	57.44	21.94	5.05	0.56	0.49	2.18	0.64	0.17	0.10	164.40	76.20	34.70	116.90	237.40	11.4394
A1-13022-373	Phase III	1B	B	60.15	21.69	4.87	0.46	0.85	2.41	0.99	0.20	0.13	170.00	101.20	42.20	48.10	269.30	8.259
A1-13022-374	Phase III	1B	B	59.71	21.38	3.98	0.50	0.83	2.49	0.99	0.23	0.21	154.40	225.50	39.10	51.00	249.30	9.691
A1-13022-375	Phase III	1B	B	56.51	21.97	4.15	0.43	1.00	3.11	1.30	0.34	0.12	193.70	203.70	34.10	82.30	228.50	11.059
B1-1518-12	Phase II	1D	B	60.98	23.03	3.89	0.52	0.27	1.51	0.57	0.10	0.06	90.10	79.10	22.50	60.80	305.20	9.0882
A1-14001-145	Phase I	2A	A	57.11	18.49	5.01	0.31	1.85	4.05	1.83	0.39	0.37	234.20	141.50	30.40	107.40	143.40	10.604
B1-1390-6	Phase II	2A	A	58.54	16.01	3.58	0.31	1.31	4.09	1.39	1.09	0.15	211.90	92.40	44.20	84.40	223.60	13.533
B1-1418-13	Phase II	2A	A	50.70	19.53	5.38	0.36	4.78	4.26	2.57	0.22	0.21	227.70	393.80	30.60	152.70	163.60	11.979
B1-1523-3	Phase I	2A	A	63.42	14.10	3.09	0.29	1.37	3.93	1.23	0.84	0.31	198.00	77.70	30.80	73.60	279.50	11.417
C1-1507-3	Phase II	2A	B	58.79	17.01	5.29	0.41	1.09	3.05	0.88	0.12	0.57	194.60	249.40	33.50	102.50	176.80	12.786
C1-1544-8	Phase II	2A	B	56.99	16.37	4.10	0.28	1.20	3.26	2.07	0.23	0.15	201.30	246.30	6.50	81.40	250.90	15.343
C1-1654-2	Phase I	2A	A	54.24	19.81	6.13	0.30	1.95	4.09	1.56	0.24	0.15	278.40	162.30	26.20	156.60	178.30	11.535
C1-1654-3	Phase I	2A	A	55.09	17.50	5.02	0.27	2.34	3.96	1.48	0.23	0.08	203.70	159.30	25.20	110.00	146.00	14.036
C1-1671-3	Phase I	2A	A	55.67	16.40	3.96	0.28	1.51	5.00	1.96	0.73	0.68	202.50	210.80	41.10	126.00	224.40	13.801
D1-1309-1	Phase I	2A	A	57.67	18.17	4.86	0.26	1.16	4.41	1.64	0.16	0.09	228.30	138.20	17.50	127.00	167.90	11.5809
A1-13060-1	Phase III	2B	B	57.30	15.14	3.37	0.25	0.97	4.07	1.43	0.21	0.34	195.10	119.70	33.30	81.50	147.10	16.922
B1-12005-2	Phase III	2B	B	56.61	20.11	4.66	0.32	2.80	2.32	1.01	0.23	0.31	160.40	291.30	40.70	109.50	258.60	11.646
GBW07109: Experimental Value				53.65	17.70	7.41	0.47	1.37	7.65	0.54	7.04	0.06	128.02	1168.7	30.22	117.60	1548.31	4.22
GBW07109: Certificate				54.48	17.52	7.27	0.48	1.39	7.48	0.65	7.16	0.02	130.00	1160.00	24.70	112.00	1540.00	4.35
% error				−1.53	1.02	1.87	−1.25	−1.15	2.27	−16.92	−1.68	205.56	−1.53	0.70	22.34	5.00	0.54	N/A
NCSDC87103: Experimental Value				71.67	12.01	3.95	0.71	1.32	2.32	1.03	2.36	0.13	85.45	216.43	23.95	45.59	321.93	3.33
NCSDC87103: Certificate				72.92	12.28	3.78	0.69	1.44	2.16	1.14	2.20	0.11	91.00	227.00	22.00	48.00	331.00	3.12
% error				−1.71	−2.19	4.52	3.04	−8.54	7.22	−9.91	7.18	18.18	−6.10	−4.65	8.85	−5.02	−2.74	N/A

analysis and petrographic work. Additionally, 9 clay samples (labelled SED) have been analysed from areas around the site in order to obtain information about raw material and potential provenance of the pots. UTM coordinates of each sediment sample have been recorded and uploaded in a GIS (Fig. 8).

Loss on ignition, measuring the amount of organic and other volatile compounds in the samples, was calculated with 1.250 g of soil, using the protocol described in Hoogsteen et al. (2018). After which, these 1.250 g of sample were ground with 0.250 g of wax binder (Panalytical Ultra-wax) in an agate ball mill for 10 min. The resulting mixture was placed in a die press and pressed at 8 tonnes for 30 s to produce a 13 mm diameter pellets 6–7 mm in thickness. The pressed pellets were run on a Panalytical Zetium WD-XRF with a 4 kW rhodium anode tube. The samples were run using Panalytical's proprietary Omnian standardless calibration specifically calibrated for 13 mm diameter pellets. The analysis time for each sample was 40 min. The elements analysed for were Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5, K_2O, CaO, TiO_2, Fe_2O_3, Rb, Zn, Sr, Y and Zr). A principal components analysis (PCA) (Orton and Hughes, 2013: 176–180) was conducted using SPSS v.22 to plot the similarity of the 'chemical fingerprint' of each sample (Fig. 10). A two-step cluster analysis was utilised to define the different groups (I-III). P_2O_5 was analysed for but excluded from the PCA as it is potentially affected by various post depositional processes (Holliday, 2004) limiting its usefulness for geochemical fingerprinting of this type.

4. Results

4.1. Macroscopic analysis

Macroscopic and stereomicroscope analysis showed that Fine Orange Ware had consistently fine-grained matrices, usually orange throughout the cross-section (Fig. 4, 1-2). However, grey and white cores can also occur. Their exterior surfaces are often burnished whereas the internal surface is often smoothed. Vaccean Common Wares have coarse matrices with rounded and subrounded inclusions (Fig. 4, 3). The majority of samples of this group show no surfaces treatment, but a few were slipped in order to obtain particular colours. Black or orange are the most common colour, with some sherds exhibiting both. Grey Ware sherds have a very fine grained matrix with grey-white coloured cross-section and sometimes orange cores (Fig. 4, 4). Black Burnished Vessels shows black fine-grained matrices with rounded inclusions (Fig. 4, 5). Both exterior and interior surfaces have been intensely burnished, hiding most of the traces of the use of the potter's wheel. Proto-arevaci Ware is relatively coarse presenting angular inclusions in a black matrix (Fig. 4, 6). External and internal burnish is also detected in this production. Roman Common Ware present matrices very similar to Fine Orange Ware, but without burnish or painting on their surfaces (Fig. 4, 7). Two different kind of matrices have been noted for Roman Cooking Ware. The first one has a very coarse sand matrix black or sometimes brown in colour (Fig. 4, 8), while the second presents orange matrices

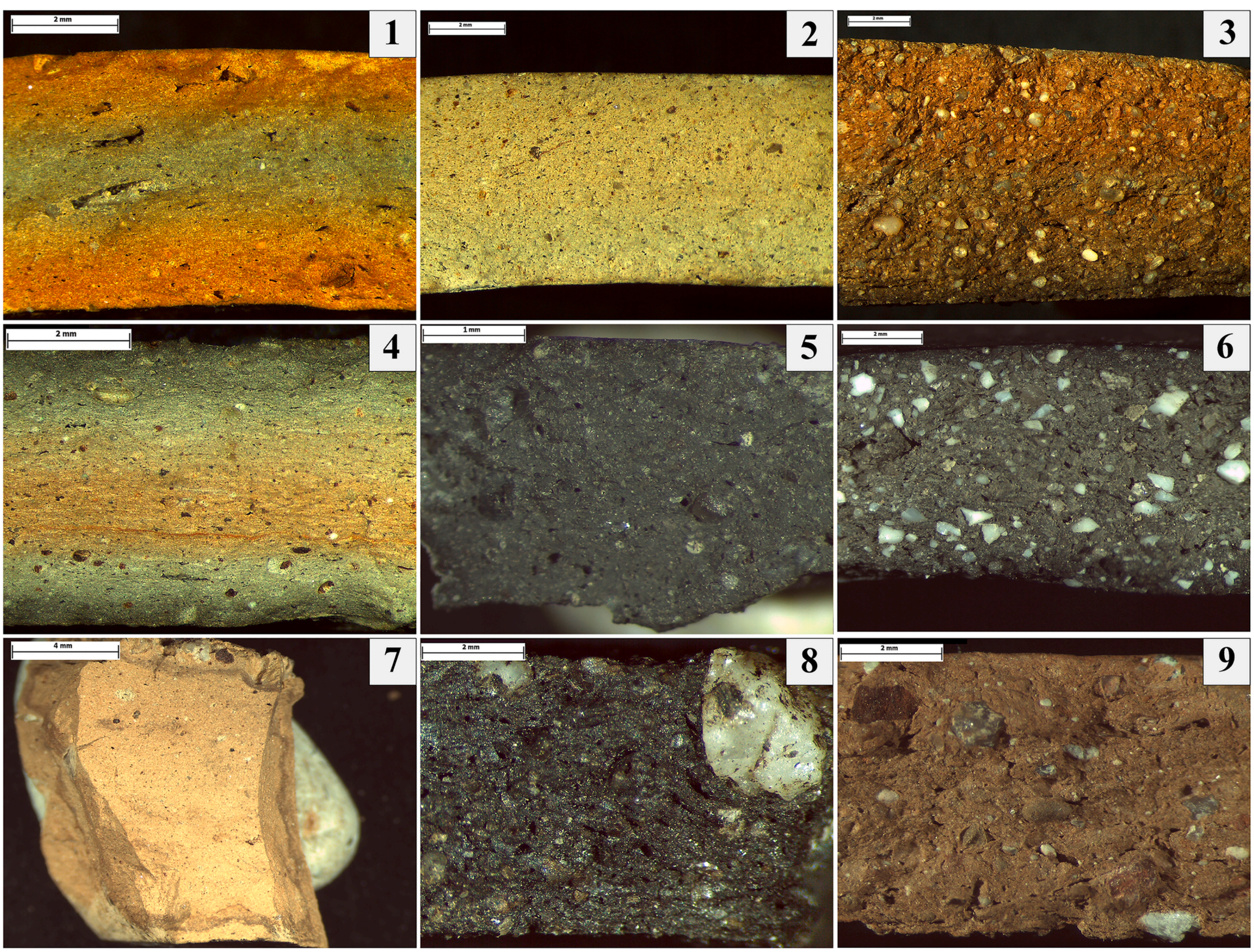

Fig. 4. Matrix photographs of Fine Orange Ware (1-2), Vaccean Common Ware (3), Grey Ware (4), Black Burnished Vessel (5), Proto-arevaci Ware (6), Roman Common Ware (7), Roman Cooking Ware (8-9). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

with subangular and elongated inclusions (Fig. 4, 9).

4.2. Petrographic analysis

Five main fabric groups and a number of subfabrics were defined through petrography. A full qualitative and quantitative breakdown of the petrographic data is provided in Supplementary Information (Appendix 5). Summary descriptions are provided below.

Fabric 1- Fine Clay Rich Fabric with Quartz.

Fabric group 1 (Fig. 5) is the most prevalent in the ceramic assemblage with 20 individuals from all chronological contexts. All subfabrics in this group are dominated by a non-plastic fraction (3–10%) composed mostly of quartz. Plagioclase, biotite, muscovite, chlorite, clay and opaque (probably mostly iron rich) inclusions, and indeterminant metamorphic rock fragments are also noted rarely in this fabric group, usually ranging from 100 μm to 500 μm in size. The matrix of this group is usually optically-active, with the exception of two samples (E1-1318-21 and B1-1232-4). The fabric can be divided into four subgroups (A-D) depending on matrix characteristics and grain type and size. Subfabric 1A (Fig. 5, a-e) includes 12 samples from all chronological contexts. This subfabric is characterised by a fine texture with frequent rounded and subrounded fine sand-sized quartz grains. Burnishing and painting is sometimes associated with this fabric group (Fig. 5, d-e). Subfrabric 1B (Fig. 5, f-h) contained 4 samples from Phase III and 1 sample from Phase II. 1B differs from the other subfabrics of this group as it is slightly coarser. Additionally, iron staining and opaque inclusions are more frequent compared to samples from 1A, but the inclusions are not as large as those of samples of 1C. Some samples of fabric 1B lack optical

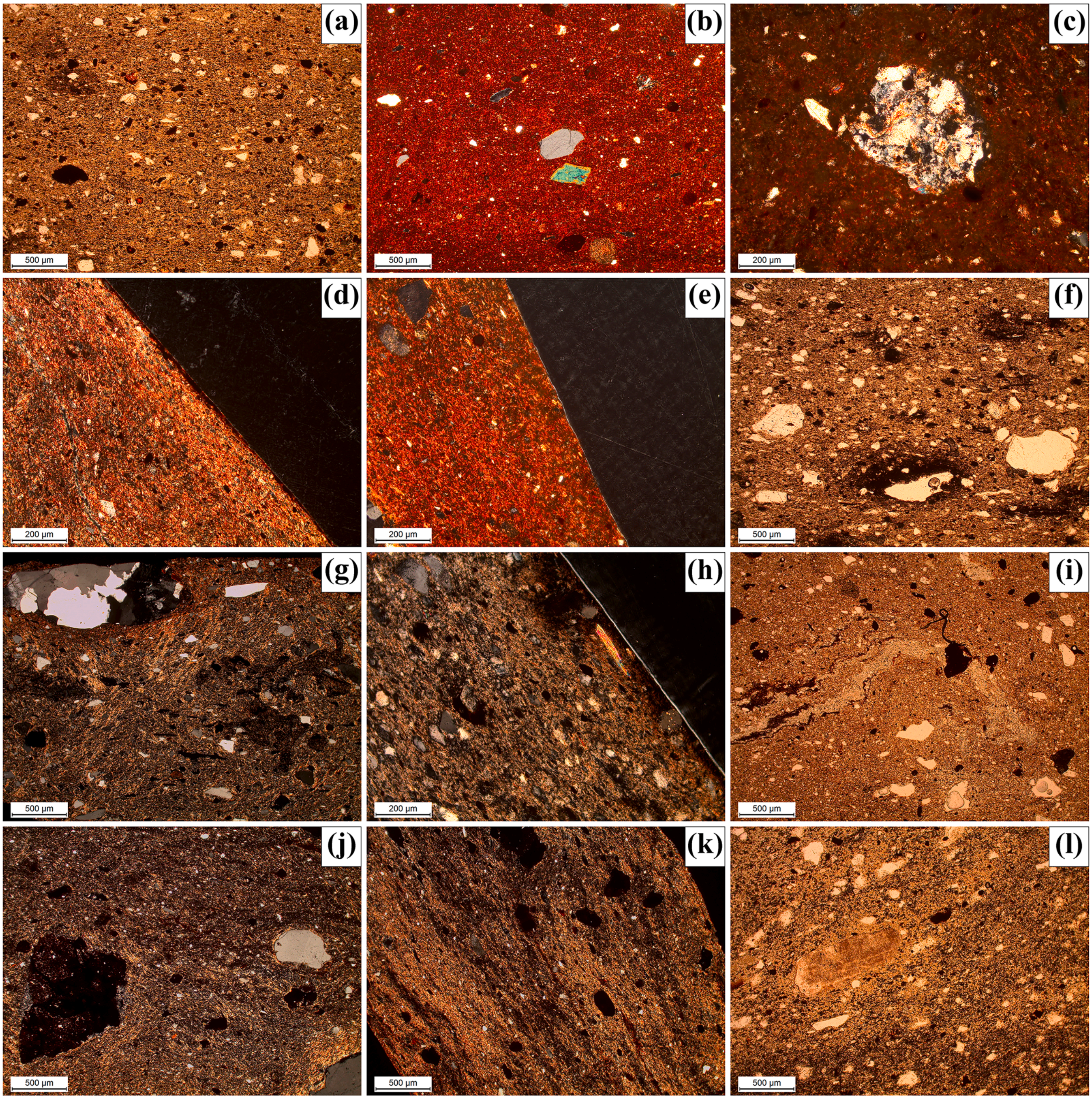

Fig. 5. Photomicrographs of ceramic fabric group 1, taken in PPL (a, f, I, l) and XPL (b-e, g-h, j-k). Fabric group 1A (a: A1-13008-3; b: C1-1634-4; c: B1-1232-4; d: D1-1137-5; e: C1-1634-4), fabric group 1B (f, h: A1-13022-373; g: A1-13022-375), fabric group 1C (i: A1-13022-2; j-k: A1-13023-2.1), fabric group 1D (l: B1-1518-12).

activity at the edges of the section (Fig. 5, h). Subfabric 1C (Fig. 5, i-k) contains two samples, A1-13022-2 and A1-13023-2.1 dating to Phase III. This subgroup is differentiated by two attributes. Firstly, the presence of medium and coarse-sized opaque grains. Secondly, it shows a streaked matrix indicating either incomplete clay mixing or natural bioturbation (Quinn, 2013: 168; Ho and Quinn, 2021). Finally, subfabric 1D (Fig. 5, l) is represented by one sample, B1-1518-12, from Phase II, and is characterized by the infrequent presence of shale.

Fabric 2 – Coarse Quartz Rich Micaceous Fabric

Fabric group 2 (Fig. 6, a-e) is composed of coarse wares, mainly cooking pots. It is the second largest group, with 13 samples found in all phases. The sherds belonging to this fabric contained 20–45% total non-plastics, and exhbited planar and elongated channels voids in all samples. This fabric can be divided into two subgroups (A-B) depending on grain type and size. Subfabric 2A (Fig. 6, a-c) consists of 11 samples from all phases. This fabric is characterised by frequent rounded and subrounded coarse and medium sand-sized grains of quartz. Clay rich and opaque inclusions (probably iron rich) are also present. Coarse and medium sand-sized grains of plagioclase, muscovite, biotite, chlorite and indeterminant metamorphic rock occurred rarely. The groundmass presents both optically active and sintered optically inactive areas, indicating high firing temperatures, though perhaps for a relatively short duration. In addition, two samples (A1-14001-327 and D1-1309-1) showed signs of clay mixing or bioturbation (Fig. 6, c). Subfabric 2B (Fig. 6, d-e) is represented by 2 samples (A1-13060-1 and B1-12005-2) recovered from Phase III. Both are poorly sorted, with subangular to angular coarse, medium and fine sand-size grains of quartz. Grains of the same size of K-Feldspar, muscovite, biotite and metamorphic rocks occurred commonly.

Fabric 3, 4 and 5

The rest of the petrofabrics are poorly represented. Fabric group 3, is a coarse Quartz Rich Fabric (Fig. 6, f), containing 2 samples (E1-1301-1 and E1-1318-9) dating to Phase I. It is a relatively coarse fabric, with 20–25% total aplastics and a well-sintered and optically active groundmass. The mineralogy is almost entirely composed by rounded and subrounded fine sand-sized grains of quartz. Fabric group 4, or Micaceous Fabric (Fig. 6, g-h) consists of 2 samples, B1-1230-25 and C1-1617-3, both Roman *paterae* recovered from Phase III and II respectively. It is characterized by the presence of coarse and medium sand-size inclusions of muscovite and opaque (probably mostly iron rich) inclusions. Finally, fabric group 5, or Calcite-tempered Fabric (Fig. 6, i), is represented by the sample B1-1439-10, recovered from Phase I. It is characterized by the presence of subangular coarse and medium sand-sized grains of calcite. The angularity of the calcite indicates its addition as temper (Fabbri et al., 2014: 1902).

Petrofabric groups map well onto the different wares documented at Pintia. Fine Orange Ware, Grey Ware, and Roman Common Ware individuals belong fabric group 1, suggesting similar raw materials were used to produce different kinds of fine ceramics. However, the differences between the subgroups may indicate some technological changes depending on the kind of ware being produced. For example, fabric group 1B is used only for Grey Ware sherds. Fabric group 1C consists of

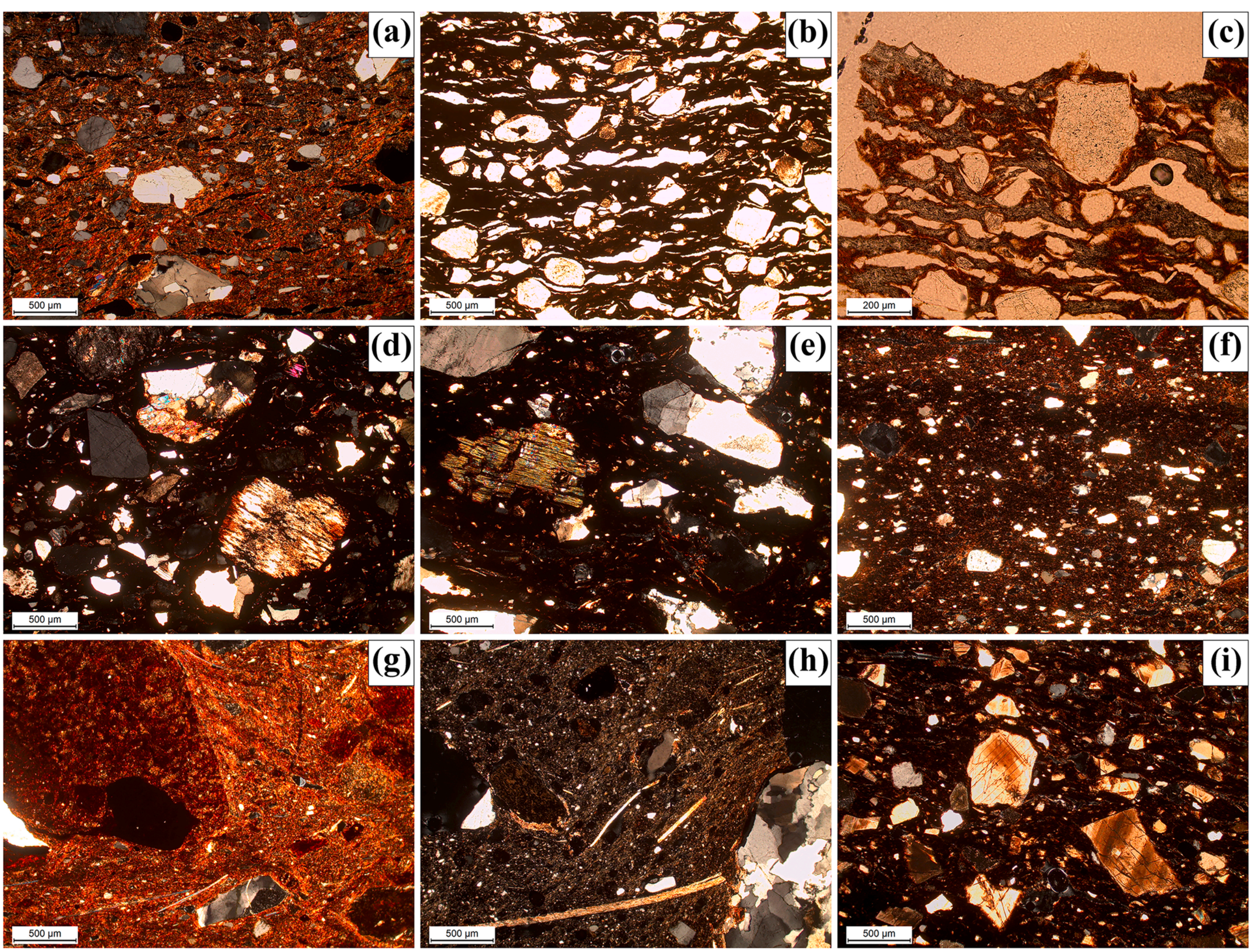

Fig. 6. Photomicrographs of ceramic fabric groups, taken in PPL (b, c) and XPL (a, d-i). Fabric group 2A (a: C1-1671-3; b: C1-1654-3; c: A1-14001-327), fabric group 2B (d: A1-13060-1, e: B1-112005-2), fabric group 3 (f: E1-1318-9), fabric group 4 (g: B1-1230-25; h: C1-1617-3), fabric group 5 (i: B1-1439-10).

Fine Orange Ware recovered exclusively from Phase III (post Roman Conquest) and shows more streaking and large opaque bodies (probably iron rich clay pellets) than earlier examples, which points to less complete homogenisation of the clay (Ho and Quinn, 2021). Perhaps, this reflects more haste in production, but at least highlights changes in the way of making this paste after the arrival of Romans. During Phase I, fabric group 3 is used to produce Black Burnished Vessels and Fine Orange Wares, which suggest again the selection of the same raw material for the production different specialist ceramic styles. Fabric group 2 evidences two different ways of making cooking pots in the settlement. Firstly, fabric group 2A is used for Vaccean Common Ware, whereas fabric group 2B is used for Roman Cooking Wares, particularly pots. Rarely, this fabric is used to make other kinds of large vessels, such as fabric 2A utilised for a *pithos* categorised with the orange wares. New ways of making ceramics for cooking are also attested by fabric group 4, which uses a micaceous clay for Roman Cooking Wares, specifically dishes for frying. Finally, the calcite-tempered vessel belonging to fabric group 5 is suspected to be an import, because it is the only attestation of this practice at Pintia. Additionally, its typology is a good fit with the vessels from the celtiberic region of *arevaci*. Fabric 5, thus, evidences likely exchange between the Upper and Middle Douro Valley communities.

4.3. XRD analysis

XRD results (Supplementary Information, Appendix 3 and 4; Fig. 7) reinforced and mineralogical data obtained from petrography while shedding light on firing temperatures used for the pottery repertoire from Pintia. There is limited evidence for diachronic variation in firing temperatures for the Vaccean ware groups that continue into the Roman period, further supporting the petrographic results that show the dominant production modes for locally produced pottery go largely unchanged after the Roman conquest. 43 samples analysed via XRD show firing temperatures at or around 800 °C. Fine Orange Ware, Vaccean Common Ware, Grey Ware, Roman Cooking Ware and Black Burnished Vessels are represented within this range. The detection of neoformed minerals including one or more of diopside, gehlenite, anorthite and spinel in 59 samples indicates firing commonly reach temperatures between 800 and 950 °C. This range includes only Fine Orange Ware, Vaccean Common Ware, Roman Cooking Ware and Proto-arevaci Ware. Mullite, iindicating temperatures reaching 1100 °C, was only recorded in a few individuals, 3 Grey Ware samples and 3 Roman Cooking Ware, which suggests higher firing temperatures in some pottery can be associated with phases II and III. In summary, the majority of our samples were fired between 800 °C and 950 °C, in agreement with previous analyses of ceramic assemblages from the Iberian Peninsula during the Iron Age, including those from Vaccean (Escudero, 1999a), celtiberic (García Heras, 1997: 170–174; Igea et al., 2008: 50; 2013: 13; Sánchez-Climent et al., 2018: 242, 246), tartesic (Barrios et al., 1994: 40) and iberic (González Vilches et al., 1985a; 1985b; Tsantini et al. 2005: 856; Tsantini, 2007: 271-290; Cultrone et al., 2014: 10807) regions.

4.4. Geochemical analysis

Contrary to some similarities in modes of production highlighted by petrography and XRD for locally produced vessels from pre- and post-Roman conquest periods, geochemical analysis indicates changes in the raw material sourcing of the Vaccean and Roman period productions. 36 ceramic and 9 clay samples were analysed from groups defined by the petrographic analysis and the local geology (Fig. 8) respectively. The geological context is a river basin surrounded by tertiary limestones with the intercalation of marls, dolomites and gypsum formations. The riverbanks are formed for an alluvium of quaternary sediments composed of sands and gravels including quartz and calcareous materials. This formation grows over a Middle Miocene sands and gravels which are eroded by the river (Fig. 9). In addition, fine-grained sedimentary rocks and sandstones also occur in the upper part of the basin (Calonge, 1995).

Elemental Concentrations (Table 1) are expressed in wt% for the major/minor oxides and ppm for trace elements. As detailed above, 13 elements showing the best agreement with CRM material were included

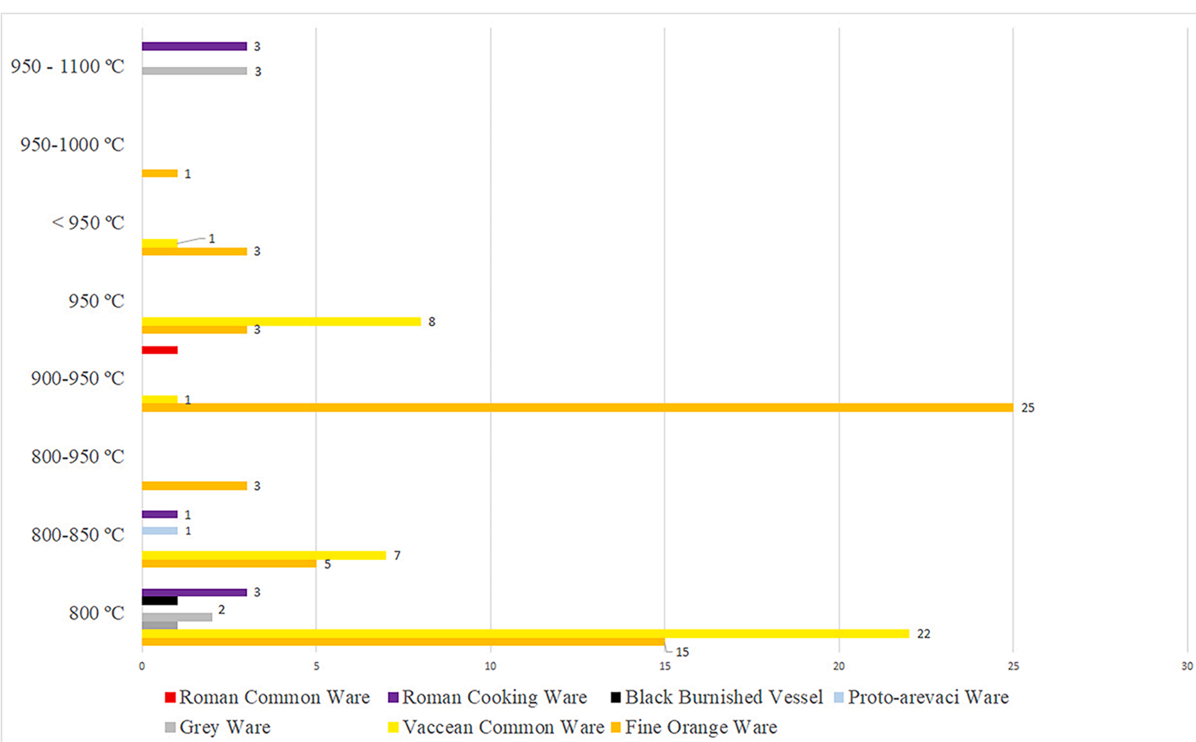

Fig. 7. Firing temperature determined by XRD along with ware groups.

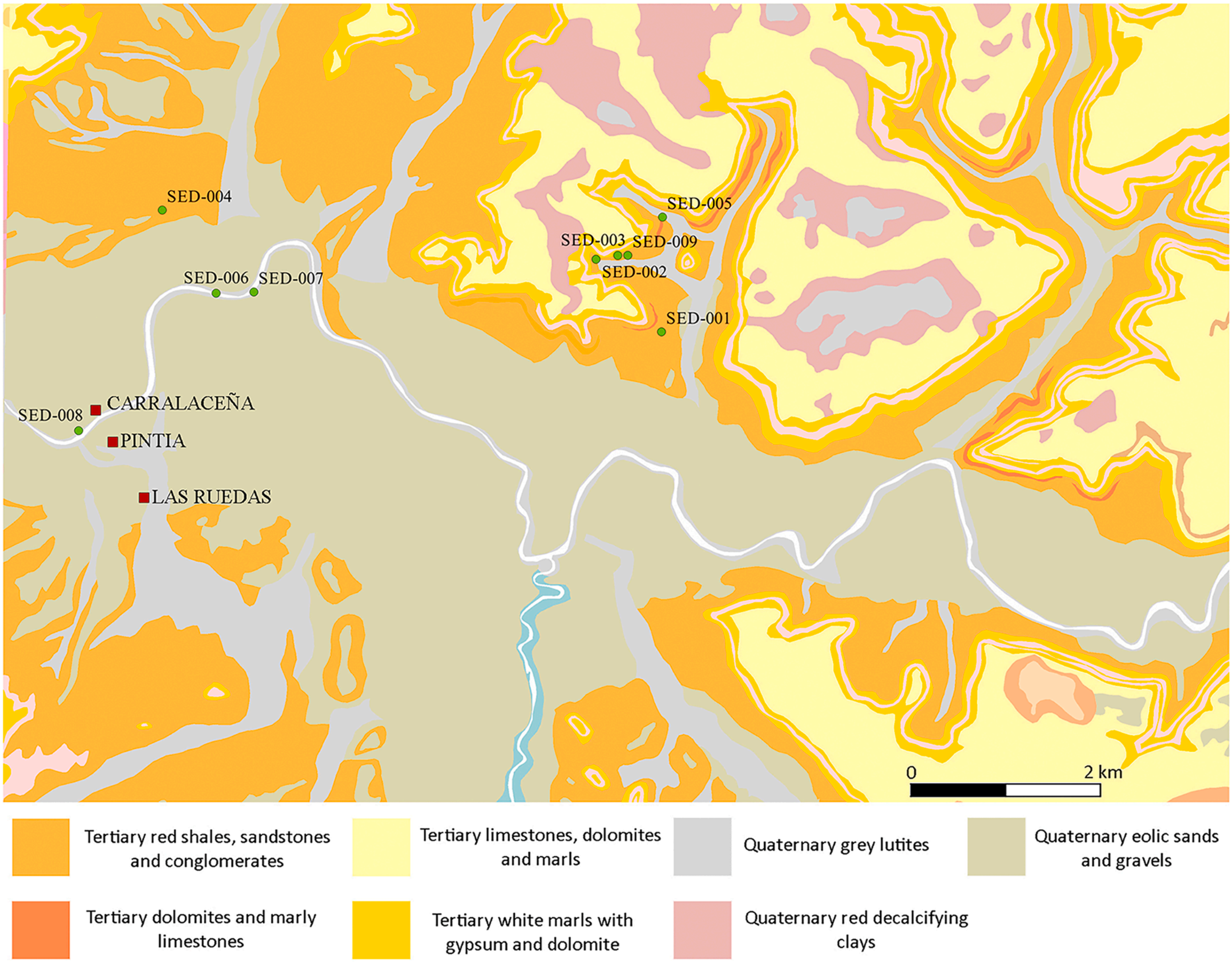

Fig. 8. Geological map with the location of the sedimentary samples taken for this study in relationship to Pintia (based on sheet 374 of the Geological Map of Spain, Instituto Geológico y Minero—MAGNA series, scale 1:50.000, IGME 1992).

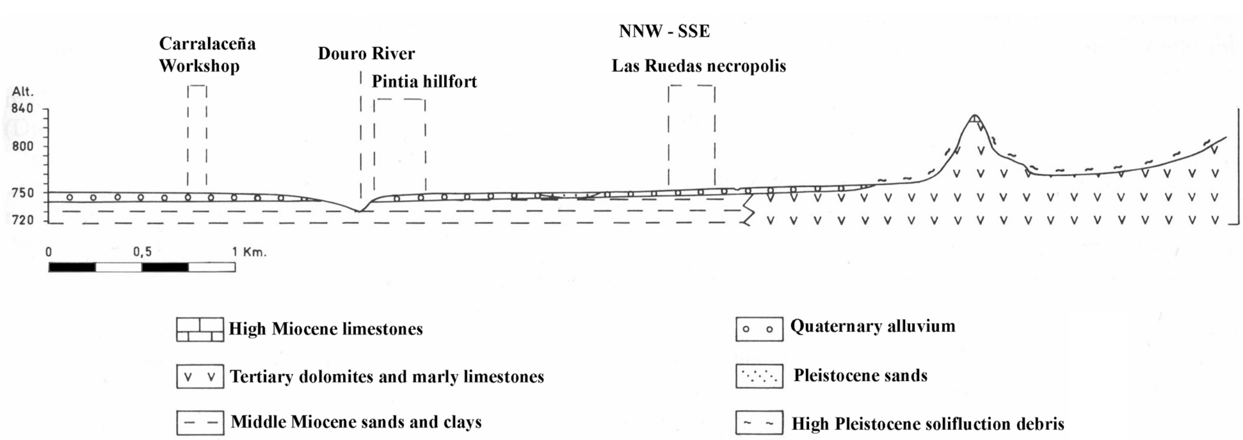

Fig. 9. Geomorphological profile of the south riverbank, showing the location of archaeological sites (based on Calonge, 1995: 31, Fig. 5).

and plugged into a Principal Components Analysis. These elements allowed for a clear separation of the dataset into distinct geochemical groups. 3 components were extracted explaining 74.42% of the variation (see Supplementary Information, Appendix 6 for loading plot). Plotting factors 1 and 2, and using a two-step cluster analysis we identified 3 geochemical groups (Fig. 10). Group A is almost entirely composed of pottery recovered from Phase I with a few sherds from Phase II. All vessels in this group belong to petrofabrics 1A and 2A. Group B, on the other hand, is composed mostly of samples from Phase III and Phase II. All petrofabrics are represented in group B except for 5. Group C is

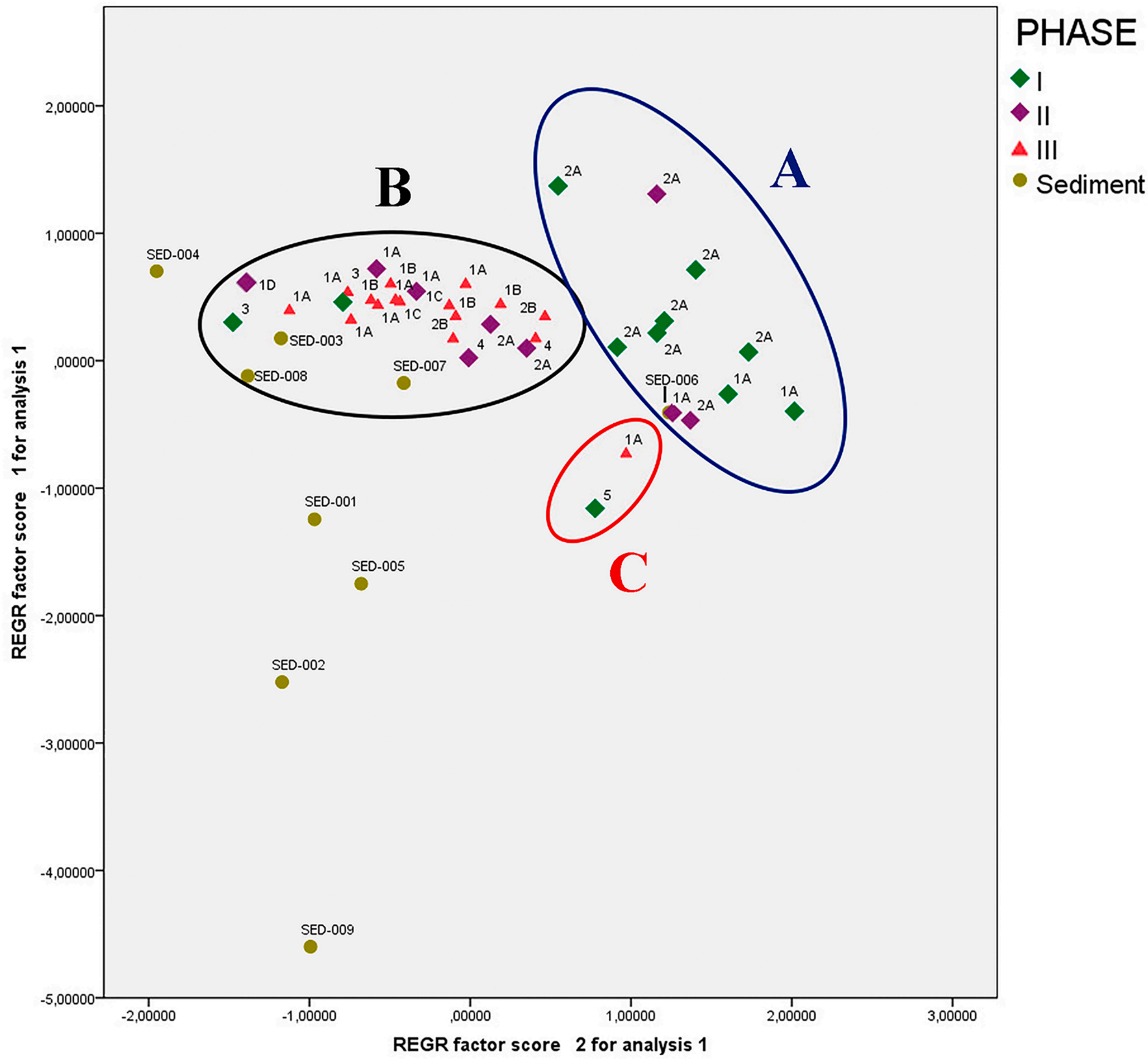

Fig. 10. Plot of the factor scores generated from the principal component analysis of the WD-XRF chemical data and geochemical groups. Component 1 explains 38.52 % and component 2 explains 23.80% of the variance respectively.

composed of two samples. These sherds are a Roman Common mortar (B1-1232-4) belonging to petrofabric 1A and a Proto-arevaci bowl (B1-1439-10) belonging to the calcite-tempered petrofabric 5.

The two main chemical groupings as determined by the PCA exhibit a broadly similar chemistry, though distinct compositional differences can be observed. The SiO_2, TiO_2, concentrations are higher in group B samples on average, compared to samples from group A. Samples from group A tend to be higher in Fe_2O_3, K_2O, MgO, Rb and Zn relative to group B samples. The two samples from group C are much higher in CaO relative to samples in groups A and B.

Maniatis and Tite (1981), classify ceramics as non-calcareous if their CaO concentrations are below 6 wt%, with vessels exceeding this value termed 'calcareous'. The majority of our samples fall into their non-calcareous, catagory with CaO concentrations between 0.27 and 5.94 wt%. Only the two sherds from geochemical group C can be considered calcareous. The Roman Common mortar B1-1232-4 with 11.132 wt% and the Proto-arevaci bowl B1-1439-10 (calcite tempered) with 14.812 wt%. Therefore, potters at Pintia in all periods favour the utilisation of clays with a low Ca content for potting.

Hein and Kilikoglu (2020) have recently highlighted the potential difficulties associated with comparing raw clay materials to finished ceramics, where the raw materials have been significantly processed. This might include the removal of organic material and coarse inclusions, and then the addition of tempering materials, all of which would be expected to cause some variation in the chemical fingerprint of sediments relative to the finished ceramics. Of the geological samples collected as possible raw material sources, sediments 1, 2, 5 and 9 can be excluded due to their high concentrations of CaO (22% on average). These sediments are also much higher in MgO and lower in K_2O than any of our ceramic samples. Sediments 1 and 5 also show high concentrations of Sr, which contrasts with lower concentrations in the ceramic assemblage. A number of sediment samples are closer matches to the ceramic samples, but show variations in some elements. These include 3, 7, 8 (group B) and 4 (just outside of group B). The raw materials are lower in Fe_2O_3 and Al_2O_3 with sample 4 also being higher in SiO_2 relative to the ceramics in the assemblage. It is possible that these sediments were used for producing pottery from group B at Pintia, with processing by the potters as described above accounting for the chemical variation observed. Sediment 6 represents a good match for a raw material source for group A as its geochemical composition across all elements aligns well the averages for samples from that group.

5. Discussion

This study highlights the existence of a robust local pottery tradition that continues after the arrival of Romans, albeit with some changes (Blanco, 2015). Geoprospection has identified local materials that are chemically similar to examples in the ceramic assemblage, strongly suggesting the majority of pottery found at Pintia was produced locally.

The petrography has shown that similar raw materials and preparations are used to produce a range of finishes and styles across the 3 most recent phases at the site. For example, petrofabric 1 includes Fine Orange Wares, Grey Wares and Roman Common Wares. Various surface treatments and firing atmospheres were used to produce a range of colours and decorations, but in the majority of cases, similar non-calcareous quartz rich recipes were used. These wares would have produced a hard fabric that could be fired to higher temperature without the risk of spalling posed by highly calcareous fabrics.

Despite the continuation of the local pottery traditions, the arrival of Romans brings some significant changes to the Vaccean ceramic repertoire. Petrofabric 4 is a micaceous fabric used for types made for frying, representing a completely new way of cooking. Petrofabric 2B represents a new way of making cooking pots that are coarser than variants represented by petrofabric 2A. The differences observed after the Roman occupation can be attributed to one or a combination of different degrees of raw material processing (e.g levigation and/or sieving), tempering or changes in raw material source. The former are suggested by the petrography while the latter is suggested by the geochemical analysis. Finally, individuals from petrofabric 1C, which belong to Fine Orange Wares from Phase III, show evidence of poorer homogenisation of clays, perhaps reflecting more haste in the preparation of some fabrics after the arrival of the Romans.

Shifts in production during Roman times are perhaps most clearly evidenced by the geochemistry. XRF analysis shows a change in the chemical composition of raw materials under Roman rule in Phase III, a process which already began during Phase II. In many cases, these differences are not perceptible in thin-section, which suggests a shift to new, but related and locally available, clay sources rather than a wholesale change in production modes. In pre-Roman times (Phase I and II) clays represented by both geochemical group A and B were exploited. However, the use of clays from geochemical group B intensifies during Roman rule in Phase III. The reasons for these shifts are unclear at present, though it could perhaps be related to the increasing scale of production during the Roman period (Padilla, 2017: 102–103) requiring the exploitation of different resources. In the case of ceramic production at Pintia, these factors may have necessitated the use of more heterogenous clay quarries near the site which were previously avoided. In any case, the geochemical divisions suggest either a change in clay resources and/or changes in the processing of raw clays and tempering. Finally, the identification of SED-006 as the best candidate for raw material source of group A, raises some questions as it is located further afield than then other clay sources (e.g. SED-008) located right next to the Carralaceña workshop. However, SED-006 is less calcareous than SED-008, which suggests that it was important for potters both pre and post Roman conquest to seek out non-calcareous materials to work with even if slightly further afield.

Fabric Group 5 in geochemical group C shows the only occurrence of calcareous vessels at Pintia. As discussed above, the vessel is likely an import to Pintia from celtiberic sites in the Upper Douro River. The documentation of a similar fabric with added calcite as temper in the Iron Age hillfort of Numancia (García-Heras 1997: 143, 1) suggests limited exchange of this kind of ware during the Vaccean period. The other calcareous example is the Roman Common Ware mortar B1-1232-4. Petrographically, it is indistinguishable from other examples from fabric 1A, which demonstrates technological similarities with Fine Orange Wares produced during Vaccean and Roman times. The Roman mortar, however, has a high CaO concentration, indicating the use of calcareous clays for its production. Our work shows these clays were mostly avoided for potting at Pintia. As such, it remains unclear whether this mortar was made at Pintia or comes from elsewhere as these types were widely produced across Iberia.

6. Conclusions

The archaeometric characterization of pottery from the Iron Age Hillfort of Pintia represents an increase in our understanding of Vaccean pottery production and the effects of the Roman conquest. 5 main petrofabrics were observed. Similar clays and tempering materials, albeit used in different proportions, were used to manufacture a range of vessels represented by petrofabrics 1 and 2 in all phases. On the other hand, some petrofabrics, such as 3 fall out of use with the arrival of the Romans. Some changes to the processing and tempering of materials are observed after the Roman conquest. For example, some fabrics are less homogenised as in the case of Fabric 1C or have a coarser and more heterogeneous sand fraction in the case of fabric 2B, suggesting some changes to aspects of the *Chaîne Opératoire*. Petrofabric 4 represents the introduction of a new way of producing cooking wares primarily intended for frying, a new culinary tradition brought with Roman rule. Finally, fabric 5 evidences interaction between groups in the Upper Douro valley and Pintia, reinforcing previous suggestions of linkages by scholars based on the occurance of painted pottery with white colours in Vaccean hillforts originating in Numancia (Blanco, 2018b).

The geochemistry supports the petrographic and XRD data, showing that potters drew on a range of locally available materials and technological strategies to produce an assortment of vessels. The geochemical data indicates a change in the use of raw materials preferred for potting. During Vaccean times (Phases I and II) a wider range materials were used represented by geochemical groups A and B. In contrast a more limited range of materials were utilised during Phase III as most of the sherds belong to chemical group B. Calcareous sherds, represented by group C, are not common at Pintia, and likely represent imports to the site. Finally, the analysis of the sediments showed the closest match for a source used for group A samples (SED-006) was located 2 km from the Carralaceña workshop. When this workshop falls out use in the I century BC perhaps clays closer to the (as of yet undetermined) location of new workshop were favoured for production in Phase III (perhaps represented by SED-3, 4, 7, and/or 8). Future research will incorporate kiln samples from Carralaceña and will be aimed at gaining greater clarity as to why the sources shifted.

This study provides a more nuanced view of the impact of Roman rule on the adoption of Roman ways by local populations. Hybridization during the Iron Age of the Iberian Peninsula has not been considered in depth by scholars, who often frame cultural exchange as unidirectional – from the Romans to local communities. Recently some commentators have emphasised the role of Iron Age groups as active social agents in the 'romanization' process (Adroher, 2021), with new evidence from the northern plateau of the Iberian Peninsula showing that this process is more complex than previously considered because of the existence and retention of strong regional identities (Blanco, 2016). These points are supported by this study, which shows the continuity and predominance of local ceramic wares, relative to Roman styles during the I century AC at Pintia (Coria, 2021; Coria and Sanz, 2021). Some traditionally Roman forms are adopted in the local ceramic repertoire (Morillo et al., 2014), though with changes that suggest they are being adapted to local tastes. The evidence suggests that romanization should thus be considered a bidirectional process. Future work, we hope will continue to investigate these themes, further clarifying the processes of the transformation, adoption, and adaptation of Roman and Vaccean identity under roman rule.

In conclusion, the utilisation of an archaeometric approach has shed more light on the impacts of the arrival of Roman rule on ceramic production and utilisation at Pintia. The evidence shows broad continuity in style and in production modes suggesting some economic continuity and the maintenance of a distinct local identity at Pintia after the arrival of the Romans, despite major infrastructural and other socio-economic changes. With time, an increase in the occurrence of new decorative motifs and the adoption of new forms, such as those used for new ways of preparing food, suggest hybridity and the gradual interweaving of Roman traditions and concepts of style into established local norms.

CRediT authorship contribution statement

José Carlos Coria-Noguera: Conceptualization, Project administration, Formal analysis, Investigation, Writing – original draft, Visualization. **Kamal P. Badreshany:** Conceptualization, Project administration, Formal analysis, Investigation, Writing – original draft, Visualization. **Carlos Sanz Mínguez:** Conceptualization, Supervision, Project administration, Funding acquisition, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2021.103313.

References

Adroher Auroux, A.M., 2021. Importaciones y transferencias culturales durante la romanización de Iberia: definiciones, evidencias y análisis sobre el concepto de imitación*, De la costa al interior*. In: Fernández, C., Heras, C., Morillo, Á., Zarzalejos, M., Fernández, C., Pina, M.R. (Eds.), Las cerámicas de importación en Hispania, V Congreso Internacional de la SECAH, Ex Officina Hispánica, Alcalá de Henares, 2019. Sociedad de Estudios de la Cerámica Antigua en Hispania, Madrid, pp. 19–36.

Barrios Neira, J., López Palomo, J.L., Montealegre Contreras, L., 1994. Caracterización mineralógica y petroestructural de cerámicas protohistóricas. Boletín de la Sociedad Española de Cerámica y Vidrio 33 (1), 33–50.

Blanco García, J.F., 2001. La cerámica Celtibérica gris de imitación de vasos metálicos en el Valle del Duero: propuesta de sistematización y problemática en torno a su origen. CuPAUAM 27, 23–62. https://doi.org/10.15366/cupauam2001.27.002.

Blanco García, J.F., 2010, La cerámica vaccea, in *De la Región Vaccea a la Arqueología Vaccea* (eds. F. Romero Carnicero and C. Sanz Mínguez), 257-291, Centro de Estudios Vacceos Federico Wattenberg de la Universidad de Valladolid, Valladolid.

Blanco García, J.F., 2015, La cerámica pintada meseteña desde Augusto hasta Adriano, in *Manual de cerámica romana II. Cerámicas romanas de época altoimperial en Hispania. Importación y producción* (eds. C. Fernández Ochoa, A. Morillo and M. Zarzalejos), 429-491, Museo Arqueológico Regional, Madrid.

Blanco García, J.F., 2016. Entre la tradición y la asimilación de la cultura romana. Los vacceos a comienzos del Imperio. Vaccea Anuario 2015 (9), 52–59.

Blanco García, J.F., 2017, Cerámica común romana altoimperial de cocina y mesa, de fabricación local, en la Meseta, in Manual de cerámica romana III. Cerámicas romanas de época altoimperial III: cerámica común de mesa, cocina y almacenaje. Imitaciones hispanas de series romanas. Otras producciones (eds. C. Ferández, Á. Morillo and M. Zarzalejos), 143-236, Madrid.

Blanco García, J.F., 2018a, *Cauca vaccea. Formación, desarrollo y romanización de una ciudad,* Vaccea Monografías, 5, Centro de Estudios Vacceos Federico Wattenberg, Universidad de Valladolid, Valladolid.

Blanco García, J.F., 2018b. La cerámica vaccea decorada con pintura blanca. Anejos a CuPAUAM 3, 193–202. https://doi.org/10.15366/ane3.rubio2018.014.

Calonge Cano, G., 1995, Rasgos básicos del medio físico correspondiente al territorio vacceo del valle medio del Duero, in *Arqueología y Medio Ambiente. El primer milenio a.C. en el Duero medio* (eds. G. Delibes, F. Romero and A. Morales), 19-46, Junta de Junta de Castilla y León, Consejería de Cultura y Turismo, Valladolid.

Coria Noguera, J.C., 2021, *La cerámica del oppidum vacceo-romano de Las Quintanas, Pintia (Padilla/Pesquera de Duero, Valladolid). Estudio analítico y contextual,* Vaccea Monografías, 10, Centro de Estudios Vacceos Federico Wattenberg, Universidad de Valladolid, Valladolid.

Coria Noguera, J.C., Sanz Mínguez, C., 2021. Un pozo artesiano fallido de época romana en el oppidum de Pintia (Padilla/Pesquera de Duero, Valladolid). Oppidum. Cuadernos de Investigación 17, 149–176.

Cultrone, G., Rodriguez-Navarro, C., Sebastian, E., Cazalla, O., De La Torre, M.J., 2001. Carbonate and silicate phase reactions during ceramic firing. Eur. J. Mineral. 13, 621–634. https://doi.org/10.1127/0935-1221/2001/0013-0621.

Cultrone, G., Molina, E., Arizzi, A., 2014. The combine use of petrographic, chemical and physical techniques to define the technological features of Iberian ceramics from the Canto Tortoso area (Granada, Spain). Ceram. Int. 40, 10803–10816. https://doi.org/10.1016/j.ceramint.2014.3.072.

Dorado Alejos, A., 2019, *Caracterización de las producciones cerámicas de Andalucía Oriental y el Sudeste de la Península Ibérica: del Bronce Tardío al Hierro Antiguo (1550/1500 – 550 cal AC)*, Phd Dissertation, Universidad de Granada.

Cuomo di Caprio, N., 2007. *La ceramica en Archeologia 2. Antiche: tecniche di laborazione e moderni métodi d'indagine*. Collana di Scienze dell'antichitá, Roma.

Druc, I., Chavez, L., 2014. Pastas cerámicas en lupa digital: Componentes. Deep University Press, Textura y Tecnología.

El Ouahabi, M., Daoudi, L., Hatert, F., Fagel, N., 2015. Modified mineral phases during clay ceramic firing. Clays Clay Miner. 5, 404–413. https://doi.org/10.1346/CCMN.2015.0630506.

Escudero Navarro, Z., 1999a, Consideraciones sobre la alfarería vaccea. La producción de cerámica a torno, in *IV Simposio sobre celtíberos. Economía* (ed. F. Burillo), 275-288, Instituto Fernando el Católico (CSIC), Zaragoza.

Escudero Navarro, Z., 1999b. Datos sobre la cerámica común a torno de época Vaccea, in *II Congreso de Arqueología Peninsular* (coords. P. Bueno Ramírez and R. de Balbún Behrmann) 275–288, Vol. 3.

Escudero Navarro, Z. and Sanz Mínguez, C. 1993, Un centro alfarero de la época vaccea: el Horno 2 de Carralaceña (Padilla/Pesquera de Duero, Valladolid), in *Arqueología Vaccea. Estudios sobre el mundo prerromano en la cuenca media del Duero* (eds. F. Romero Carnicero, C. Sanz Mínguez, and Z. Escudero Navarro), 471-492, Junta de Castilla y León, Valladolid.

Fabbri, B., Gualtieri, S., Shoval, S., 2014. The presence of calcite in archaeological ceramics. J. Eur. Ceram. Soc. 34, 1899–1911. https://doi.org/10.1016/j.jeurceramsoc.2014.01.007.

Gámiz Caro, J., Dorado Alejos, A., Cabadas Báez, H.V., 2013. Análisis de cerámica prehistórica con estereomicroscopía: una guía revisada sobre la descripción de las fases de producción. CPAG 23, 365–385. https://doi.org/10.30827/cpag.v23i0.3114.

García-Heras, M., 1994a. Estudio arqueométrico de cerámica de Izana (Soria) y de otros yacimientos celtibéricos del Alto Duero. Boletín de la Sociedad Española de Cerámica y Vidrio 33 (6), 315–325.

García-Heras, M., 1994b. El yacimiento celtibérico de Izana (Soria): un modelo de producción cerámica. Zephyrus 47, 133–155.

García-Heras, M., 1997. Caracterización arqueométrica de la producción cerámica numantina. Universidad Complutense de Madrid. Phd Dissertation.

García-Heras, M., 2005, La tecnología cerámica. In *Celtíberos: Tras la estela de Numancia* (ed. Diputación Provincial de Soria), 359-366, Soria.

González Rodríguez, M., González Vílchez, M.C., García Heras, M., Arenas, J.A., 1999, La caracterización de los materiales cerámicos del yacimiento celtibérico de «El Palomar» (Aragoncillo, Guadalajara), in *Arqueometría y Arqueología* (coord. J. Capel), 143-158, Universidad de Granada, Granada.

González Vilches, M.C., González García, F., García Ramos, G., 1985a. Materias primas y datos tecnológicos de piezas cerámicas antiguas del yacimiento arqueológico de Cerro Macareno (Sevilla). Boletín de la Sociedad Española de Cerámica y Vidrio 24 (3), 173–186.

González Vilches, M.C., González García, F., García Ramos, G., 1985b. Materias primas y datos tecnológicos de piezas cerámicas antiguas del yacimiento arqueológico de Cerro Macareno (Sevilla) (II). Boletín de la Sociedad Española de Cerámica y Vidrio 24 (4), 219–232.

Grapes, R., 2006, *Pyrometamorphism*, Springer, Berlin.

Hein, A., Kilikoglou, V., 2020. Ceramic raw materials: how to recognize them and locate the supply basins: chemistry. Archaeol Anthrop Sci 12, 180. https://doi.org/10.1007/s12520-020-01129-8.

Ho, J.W.I., Quinn, P.S., 2021. Intentional clay-mixing in the production of traditional and ancient ceramics and its identification in thin section. J. Archaeolog. Sci.: Rep. 37, 102945 https://doi.org/10.1016/j.jasrep.2021.102945.

Hoogsteen, M.J.J., Lantinga, E.A., Bakker, E.J., Tittonell, P.A., 2018. An Evaluation of the Loss-on-Ignition Method for Determining the Soil Organic Matter Content of Calcareous Soils. Commun. Soil Sci. Plant Anal. 49 (13), 1541–1552. https://doi.org/10.1080/00103624.2018.1474475.

Holliday, V.T., 2004. Soils in Archaeological Research. Oxford University Press, New York.

Igea, J., Lapuente, P., Saiz, M.E., Burillo, F., Bastida, J., Pérez-Arantegui, J., 2008. Estudio arqueométrico de cerámicas procedentes de cinco alfares cetibéricos del Sistema Ibérico Central. Boletín de la Sociedad Española de Cerámica y Vidrio 47 (1), 44–55. https://doi.org/10.3989/cyv.2008.v47.i1.211.

Igme, 1992. Peñafiel: mapa geológico de España. Escala 1:50.000 (Hoja 374). Madrid: Servicio de Publicaciones, Ministerio de Industria y Energía.

Killick, D., 2015. The awkward adolescence of archaeological science. J. Archaeol. Sci. 56, 242–247. https://doi.org/10.1016/j.jas.2015.01.010.

Linares, J., Huertas, F., Capel, J., 1983. La arcilla como material cerámico. Características y comportamiento. *CPAG* 8, 479–490.

Maggetti, M., Neururer, C., Ramseyer, D., 2011. Temperature evolution inside a pot during experimental surface (bonfire) firing. Appl. Clay Sci. 53, 500–508. https://doi.org/10.1016/j.clay.2010.09.013.

Maniatis, Y., Tite, M.S., 1981. Technological examination of Neolithic-Bronze Age pottery from central and southeast Europe and from the Near East. J. Archaeol. Sci. 8, 59–76.

Matthew, A.J., Woods, A.J., Oliver, C., 1991, Spot Before The Eyes: New Comparison Charts for Visual Percentage Estimation in Archaeological Material, in *Recent Developments in Ceramic Petrology* (eds. A. Middleton and I. Freestone), 211-263, British Museum Occasional Paper 81, London.

Morillo, Á., Retuerce, M. y Salido, J., 2014, Imitaciones de *Terra Sigillata* en cerámica vaccea. Un conjunto procedente de Montealegre de Campos (Valladolid), in *As produções cerámicas de imitação na Hispania II* (eds. R. Morais, A. Fernánez and M. J. Sousa), 35-43, Monografías Ex Oficina Hispana II, Universidade do Porto, Porto.

Orton, C., Hughes, M., 2013. *Pottery in Archaeology*. Cambridge Manuals in Archaeology. Cambridge University Press, Cambridge.

Padilla Fernández, J.J., 2017. El artesanado alfarero en Iberia a finales de la Edad del Hierro y el inicio de la conquista romana: calidad vs. cantidad. Zephyrus 80, 93–112. https://doi.org/10.14201/zephyrus20178093112.

Quinn, P.S. 2013, *Ceramic Petrography. The interpretation of archeological pottery & related artefacts in thin section*, Archaeopress. Oxford.

Repiso Cobo, S., 2017. 2017, Pintia y las Pinzas. Historia de un topónimo. *Anuario Vaccea* 10, 70–80.

Romero Carnicero, F., 1984, La Edad del Hierro en la provincia de Soria. Estado de la cuestión, in *Actas del I Symposium de Arqueología Soriana (Soria 1982)* (coord. C. de la Casa Martínez), 51-121, Diputación Provincial de Soria, Soria.

Roberts, J.P., 1963. Determination of the firing temperature of ancient ceramics by measurement of thermal expansion. Archaeometry 6, 713–724. https://doi.org/10.1111/j.1475-4754.1963.tb00574.x.

Romero Carnicero, F., 1991. Los castros de la Edad del Hierro en el Norte de la provincia de Soria. Universidad de Valladolid, Valladolid.

Romero Carnicero, F., Sanz Mínguez, C., Górriz Gañán, C. and De Pablo Martínez, R., 2012, Cerámicas negras bruñidas del oriente vacceo, in *Cerámicas hispanorromanas II. Producciones regionales,* (eds. D. Bernal Casasola and A. Ribera i Lacomba), 619-638, Universidad de Cádiz, Cádiz.

Sánchez Climent, Á., 2016. La cerámica celtibérica meseteña: tipología, metodología e interpretación cultural. Universidad Complutense de Madrid. Phd Dissertation.

Sánchez-Climent, Á., Sánchez-Jiménez, C.J., Poblete, F.J., Cerdeño, M.L., 2018. Archaeometric characterization of the ceramics from two celtiberian hillforts: preliminary results. Mediterranean Archaeology and Archaeometry 18 (1), 237–253. https://doi.org/10.5281/zenodo.1165362.

Sanz Mínguez, C., 1997, *Los vacceos: cultura y ritos funerarios de un pueblo prerromano del valle medio del Duero. La necrópolis de Las Ruedas, Padilla de Duero (Valladolid)*, Arqueología en Castilla y León, Memorias, 6, Junta de Castilla y León, Salamanca.

Sanz Mínguez, C. and Velasco Vázquez, J. (eds.), 2003: *Pintia. Un oppidum en los confines orientales de la región vaccea*, Universidad de Valladolid, Valladolid.

Sanz Mínguez, C., Velasco Vázquez, J., Centeno Cea, I., Gallardo Miguel, M. A. and Olmo Martín, J. del, 2003, Pintia: nacimiento y desarrollo de un oppidum vacceo-romano, in *Pintia. Un oppidum en los confines orientales de la región vaccea* (eds. C. Sanz Mínguez and J. Velasco Vázquez, 45-65, Universidad de Valladolid, Valladolid.

Speakman, R.J., Shackley, M.S., 2013. Silo science and portable XRF in archaeology: a response to Frahm. J. Archaeol. Sci. 40 (2), 1435–1443. https://doi.org/10.1016/j.jas.2012.09.033.

Stoops, G., 2003. Guidelines for Analysis and Description of Soil and Regolith Thin Sections. Soil Science Society of America, Madison.

Tsantini, E., 2007, *Estudi de la producción i la distribució d'àmfores ibèriques en el NE peninsular atravès de la seva caracterització arqueomètrica.* Universitat de Barcelona, Barcelona. Phd Dissertation.

Tsantini, E., Buxeda, J., Gurt, J.M., 2005, Estudi arqueométric de les ámfores ibériques del Puig Castellar (Santa Coloma de Grmananet)", in *Món ibèric als Països Catalans: XIII Col·loqui Internacional d'Arqueologia de Puigcerdà. Homenatge a Josep Barberà i Farràs. Puigcerdà, 14 i 15 de novembre de 2003*, (ed. O. Mercadal), Vol. II, 853-864, Institut d'Estudis Ceretans, Puigcerdà.

Whitbread, I.K., 1989, A proposal for the systematic description of thin sections towards the study of ancient ceramic technology, in *Archaeometry: proceedings of the 25th international symposium* (ed. Y. Maniatis), 127–138, Elsevier, Amsterdam.